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Testing Magnetic Braking: The X-ray Activity of M Dwarfs in Pre-Cataclysmic Variable Systems

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Abstract. Angular momentum loss by magnetic braking is believed to be an important mechanism in the evolution of tidally-locked white dwarf (WD) binaries. We measure the X-ray emission of a sample of M dwarfs in pre-cataclysmic variable systems to examine for the first time, if the magnetic activity of secondary stars in tidally-locked white dwarf binaries is the same as that of their single main-sequence counterparts. Our results support the extrapolation of magnetic braking prescriptions derived from single main-sequence stars to tidally-locked WD binaries, and therefore support recent results that indicate magnetic braking plays a smaller role than previously proposed.

1. Introduction

Magnetic braking has been considered one of the most important mechanisms driving the evolution of tidally-locked white dwarf (WD) binary systems, such as cataclysmic variables (CVs) and proposed progenitors of type Ia supernovae (SN Ia). A late-type, magnetically active secondary star loses angular momentum as its magnetic field forces the outflowing ionised particles of its wind to co-rotate with the star out to large distances (Weber & Davis 1967). As the secondary is tidally forced to rotate with the orbital period of the system and angular momentum must be conserved, angular momentum is drained from the binary orbit, which decays to a shorter period and closer separation (Verbunt & Zwaan 1981).

This mechanism was most notably proposed to enable the secondary star in a CV to continue to fill its Roche-lobe despite shrinking in response to its mass-loss and to explain the "period gap" between 2 and 3 hr in which CVs are rarely observed (e.g. Rappaport, Verbunt, & Joss 1983). The upper end of the period gap corresponds to a Roche-lobe-filling secondary mass of $0.3 M_{\odot}$ at which point the secondary is expected to become fully-convective and hence to become unable to support a magnetic dynamo like the Sun's: Thus magnetic braking, and hence mass-transfer would switch off. However, more recent investigations of the rotational evolution of low-mass single stars indicate a much lower angular momentum loss rate that does not switch off in fully-convective stars (Sills, Pinsonneault, & Terndrup 2000; Andronov, Pinsonneault, & Sills 2003).

A key ingredient in models of magnetic braking is the dependence on rotational period of the stellar magnetic field strength, which is generated by a rotationally-driven dynamo (e.g. Sills et al. 2000). The magnetic field strength may be traced by a magnetic activity indicator such as the ratio of coronal X-ray luminosity to the stellar bolometric luminosity, $L_{\rm X}/L_{\rm bol}$. In low-mass single stars in the field or in open clusters, faster rotators have higher $L_{\rm X}/L_{\rm bol}$, until $L_{\rm X}/L_{\rm bol}$ saturates at a value of approximately 10^{-3}; fully-convective stars show very similar behaviour (Delfosse et al. 1998). The magnetic braking model used for CVs is derived from observations of single stars, whereas spin-up by tidal locking in a close binary may result in different dynamo behaviour.

We have used *XMM-Newton*'s European Photon Imaging Cameras (EPIC) to measure the X-ray flux from a sample of pre-CV systems in order to investigate the $L_{\rm X}/L_{\rm bol}$ – rotation period relation of M dwarfs in tidally-locked WD binary systems for the first time. We aim to compare it to that of single stars of the same spectral type, and hence see if magnetic braking models based on single low-mass stars are applicable to tidally-locked systems.

Table 1. Sample of pre-CVs observed by *XMM-Newton*. Data from Schreiber & Gänsicke (2003).

Name	Period [d]	Spectral Type	Distance [pc]	Obs. ID 0305980...	Exp. Time [ks]
BPM 71214	0.201	M2.5	25	201	4.1
RR Cae	0.304	M5–6	19	301	8.4
UZ Sex	0.597	M4	33	401	9.7
EG UMa	0.668	M4–5	22	501	6.1
Feige 24	4.232	M1.5	68	101	11.6
WD 1541−381	7.7	M2.5	76	701	18.9

2. Observations and Data Analysis

Our targets are listed in Table 1. They are nearby systems with orbital periods from 0.2 to 7.7 d. In all cases the WD cooling age is sufficient for tidal synchronisation to be expected. The slowest rotator is expected to lie outside the saturation zone. Spectral types of the secondaries indicate that some are likely fully-convective. Exposure times were calculated to give a detection for $L_{\rm X}/L_{\rm bol}$ as low as $10^{-4.5}$. For each star we extracted an X-ray spectrum of the source and nearby background from the most sensitive detector, the PN (Strüder et al. 2001), and fitted it in XSPEC (Arnaud 1996) in the energy range 0.3–5 keV with a spectral model typical for active late-type stars (see Güdel et al. 2007). We integrated under the model to calculate the X-ray flux in the 0.1–2.4 keV band that we could compare to results derived from the *ROSAT* PSPC detector for nearby M dwarfs (Delfosse et al. 1998). We calculated the bolometric flux for each star by applying a spectral type dependent bolometric correction to the observed 2MASS K magnitude (Skrutski et al. 2006), and so calculated L_X/L_{bol}. The comparison sample of nearby M dwarfs are single or in wide binaries. For each one we calculated rotation periods from projected equatorial velocities, $v \sin i$, and stellar radii.

3. Results

All of the M dwarfs in our sample were detected, including those whose spectral type suggests they are fully-convective. The light curve of EG UMa indicated it was undergoing a flare during our observation. Fig. 1 shows that the stars in our sample fit well into the observed relation of L_X/L_{bol} vs. rotation period for nearby M dwarfs. WD 1541−381 remains to be analysed.

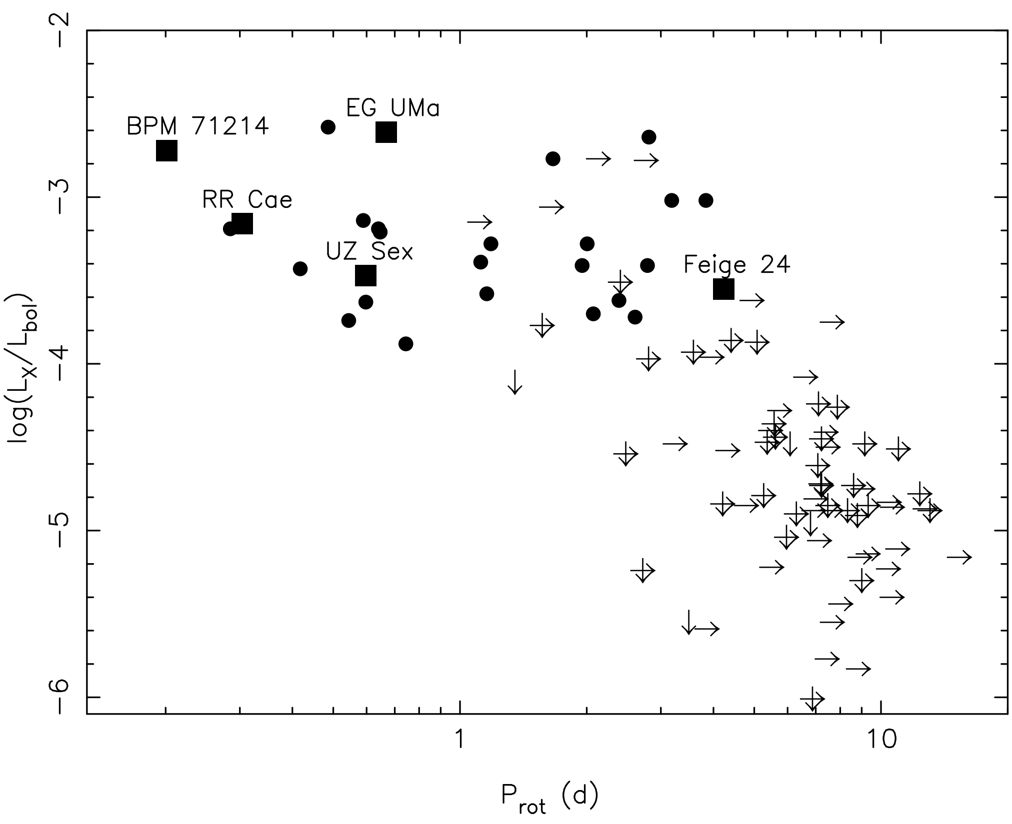

Figure 1. The L_X/L_{bol} of M dwarfs as a function of rotation period. Filled dots and arrows mark X-ray and $v \sin i$ detections and upper limits, respectively, of M dwarfs in the solar neighbourhood. Filled squares, named, mark M dwarfs in our sample of pre-CV systems.

4. Conclusions

We find that the dependence of L_X/L_{bol} on rotation period is the same for M dwarfs in tidally-locked binaries with WDs as for M dwarfs in the solar neighbourhood. This indicates that the relationship of magnetic field strength on rotation period is also the same and supports the use of magnetic braking models derived from the observed rotational evolution of low-mass stars in open clusters and the field for investigating the evolution of tidally-locked WD binaries such as CVs and SN Ia progenitors. This in turn implies that magnetic braking probably does not drive the evolution of CVs and does not explain the CV period gap.

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References

Andronov, N., Pinsonneault, M. H., & Sills, A. 2003, ApJ, 582, 358
Arnaud, K. A. 1996, in ASP Conf. Ser. 101, Astronomical Data Analysis Software and Systems V, eds. G. Jacoby & J. Barnes, (San Francisco: ASP), 17
Delfosse, X., Forveille, T., Perrier, C., & Mayor, M. 1998, A&A, 331, 581
Güdel, M., Briggs, K. R., Arzner, K., et al. 2007, A&A, in press (astro-ph/0609160)
Rappaport, S., Verbunt, F., & Joss, P. C. 1983, ApJ, 275, 713
Schreiber, M. R., & Gänsicke, B. T. 2003, A&A, 406, 305
Sills, A., Pinsonneault, M. H., & Terndrup, D. M. 2000, ApJ, 534, 335
Skrutskie, M. F., Cutri, R. M., Stiening, R., et al. 2006, AJ, 131, 1163
Strüder, L., Briel, U., Dennerl, K., et al. 2001, A&A, 365, 18
Verbunt, F., & Zwaan, C. 1981, A&A, 100, 7
Weber, E. J., & Davis, L., Jr. 1967, ApJ, 148, 217